Cerebrovascular Surgery

Volume I

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Instrumentation for Microvascular Neurosurgery

Leonard I. Malis

Principles

In the macrosurgical field it has been a tradition to develop instruments empirically, almost as an art form. These instruments have then been modified by their users over a period of time, with some being improved and some devalued. A number pass through this process of evolutionary development and become universally accepted. Such an instrument is the Leksell rongeur, for which I developed a special affection more than 20 years ago. It is a virtually perfect hand tool, combining all the attributes of adaptive engineering plus a unique artistic grace.

For any surgical procedure the surgical instruments are the interface between the surgeon and the operative field. Instrumentation should be evaluated within the constraints of the rules of systems engineering, with particular reference to the need for application of human engineering. This notion is most important for microneurosurgery, although it applies generally to tool usage. In the microneurosurgical procedures, structures as fine as 25 μm may have to be cleanly divided, while an adjacent structure of similar size must not be damaged. Dense, strong, fibrous structures may have to be resected, while soft, weak neural elements must be preserved. Blood vessel branches may have to be sealed with closure of adjacent branches or main trunks, through a range of calibers from less than 20 μm up to several millimeters. Gentle separation of tissues in anatomic planes may require a new delicacy that replaces the old blunt dissection.

The microscope provides the ability to see the fine structure as clear, large, and well lighted; it does not alter the size or shape of the surgeon's hands, which are out of the operative field. It is the surgical instrument that bridges the gap between the surgeon's hands and the microscope field. It would appear obvious that the various instruments should be large enough to fit the hand and balance at least as well as a pen or pencil. Anyone who has tried to write a long article with a stub of a pencil quickly recognizes the need for a pencil length sufficient to rest on the thenar web. Yet, the classic jeweler's forceps, for example, appears to violate this basic design for human engineering (Fig. 11.1). Merely lengthening the shank of the forceps vastly improves the instrument when used for surgery (Fig. 11.2).

The usual tools that we habitually use in our neurosurgical procedures appear very gross and obscenely large under the microscope. Inadequate approximation of tips and overlap or misalignment becomes obvious at a magnification of 10 diameters in an instrument that appears perfect to the naked eye. Handling the structures involved requires a fineness and sharp-

Fig. 11.1. Jeweler's forceps.

ness not ordinarily necessary in macroinstrumentation. There is, however, not just a difference in size; a qualitative difference is essential as well. Two classes of instruments are really required, and they are to a certain extent separate. One is a set of short microinstruments for work on surface processes where the surgeon's hand may be brought to within a few inches of the tip or even closer. Such instruments for surface work are less of a problem. A whole armamentarium of microinstruments was available to the ophthalmologist or otologist, and many were directly usable. However, many neurosurgical procedures were longer and more tedious. The lengthening of the shanks of the modified instruments to permit proper balance has already been mentioned. This handle lengthening and rebalancing also applied to those instruments borrowed from the microvascular surgeons, such as the needle holders and tying forceps.

In addition to the surface or shallow work, there is a need for instruments for working in deep cavities such as in the Sylvian fissure and along the basilar artery where a 10- or 13-cm blade length is combined with a suitable handle area to permit manipulation. Virtually every such instrument must be a bayonet-type since the fields of view are often narrow, and any other type of instrument obscures our own visualization. One variation in instrument design which we have found very useful has been the realignment of the bayonet so that the line of the bayonet handle, if continued, would run into the tip of the bayonet instead of being offset parallel, as in the usual bayonet instrument (Fig. 11.3).

This angled bayonet has a number of advantages over the parallel bayonet. First, it increases the useful viewing angle, since it places the holding hand farther away from the angle of view. Second, when the handle of a standard parallel bayonet is rotated, its tip describes an arc, with a radius equal to the offset. By contrast, when the handle of the angled bayonet is rotated, the rotation occurs around an axis that passes through the tip of the instrument. Rotation, therefore, moves the angled bayonet just as though it were a straight rod rather than a bayonet. A third advantage is noted when the bayonet is brought to the surgical area. Placing a bayonet instrument in a small field is automatically more difficult than placing a straight instrument because of the offset. The instrument is not seen by the operator until it enters the small-diameter magnified field, and it may even be possible to do serious damage with the tip of the instrument if one moves it in without some special aid or technique. With the parallel bayonet the offset increases the difficulty. The angled bayonet is moved with the same degree of nonvisual proprioceptive control as if it were a straight tool, since the line of the handle leads to the tip.

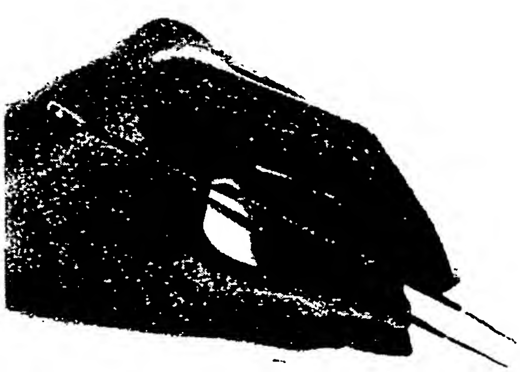

Fig. 11.2. Extended handles allow modified jeweler's forceps to rest on web.

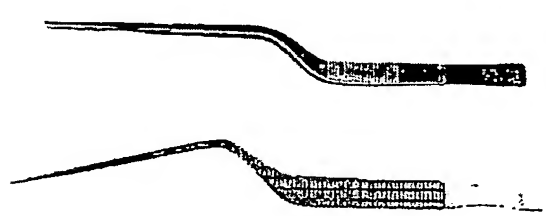

Fig. 11.3. Standard parallel offset bayonet compared with angled offset bayonet.

A number of additional tricks for placing an instrument should be mentioned, aside from the obvious methods of looking around the outside of the microscope or having an assistant guide your hand. First, one may wave the instrument across the field, well up toward the scope objective, and far from the operative level or focal plane. The blurred image is readily recognized and guided in with visual control. Another useful method consists of trying to hold one instrument in the field at all times; it is then proprioceptively easier to bring another instrument to the same point with the other hand.

Stainless steel has been almost universally used for surgical tools. Fabrication of hardened tips such as tungsten carbide inserts in stainless steel instruments is a useful method for maintaining the quality of the working surfaces. Even better is the use of total instrumentation made of titanium instead of stainless steel. The titanium instruments, either long bayonets or smaller straight configurations for surface use, are vastly superior to the older stainless design. For the same size they have greater strength and are far lighter in weight. With titanium, carbide inserts are not as important. Although carbide is harder, it is more brittle and virtually impossible to repair if broken or chipped. Titanium maintains its edge sharpness better than any stainless blade we have tried and yet has the ductility to permit repair if damaged. Titanium edges are not dulled by the steam autoclave, obviating the need for the ethylene oxide gas autoclaving that was required for the stainless microinstruments. The lightness of titanium has allowed further redesign of blade and handle thickness and balance. Again, application of human engineering requirements dictated that titanium instrumentation not be a simple recasting of existing stainless tools in the new metal. All designs are compromises involving size, strength, flexibility, weight, and balance. The new metal permitted a choice of more desirable parameters.

Color and reflectivity of shiny instruments is less of a problem than would have been expected, though sometimes glare is a real annoyance. Dulling the surface of stainless instruments was a poor answer, as they stained and mottled badly if not made with bright finishes. Titanium solves this problem. It is naturally dull, rather nonreflective, and can be made in blue-black or dark brown finishes that are impervious to any form of use or sterilization.

Shapes of handles for instruments depend on the mode of use. Jeweler's forceps have always been made with flat handles for secure finger movements. Most surgery is done with either the wrist or the fingers moving the instruments. With the handle fixed to the fingers, the instrument is held gently, but securely. Coarse rotational movements are carried out by wrist rotation and fine movements by alternately raising the thumb and lowering the forefinger or vice versa while holding the flat handles. Back and forth movements are produced by flexing and extending the proximal two joints of the supporting fingers.

Many years ago, Castroviejo introduced a round-handled needle holder, designed to be used by rotating the instrument around its axis in the fingers. The needle holder was made so that the two hemicylindrical handles closed to form a single cylinder, which made rotation of the instrument reasonable, avoiding the need for pronation and supination. Complete sets of round-handled instruments, including needle holders and forceps in both straight and bayonet configurations, are now available. I, personally, find them insecure and inappropriate. When used without rotating in the finger tips, they offer no advantage, are more likely to slip or turn, and require greater pressure to hold as compared with a flat-handled instrument. Hemicylindrical handles that do not join to form a round bar in use appear to me to be irrational. One should try both round- and flat-handled instruments and determine one's own techniques; although, frankly, I can see no excuse for a round-handled spring scissor or a round-handled bayonet instrument since neither is ever used with finger rotation, or with the two halves in contact.

Finger- and hand-grip surfaces are often left to the judgment of the least-qualified person, the commercial stylist. A heavy knurling can be awkward and difficult to clean, and a smooth surface can slip too easily. A reasonable compromise does not appear difficult to achieve. One of the worst examples, showing how human engineering can be ignored, occurs, not in microinstrumentation, but in some rongeur handles. An instrument designed for hard repetitive squeezing, which obviously needs broad

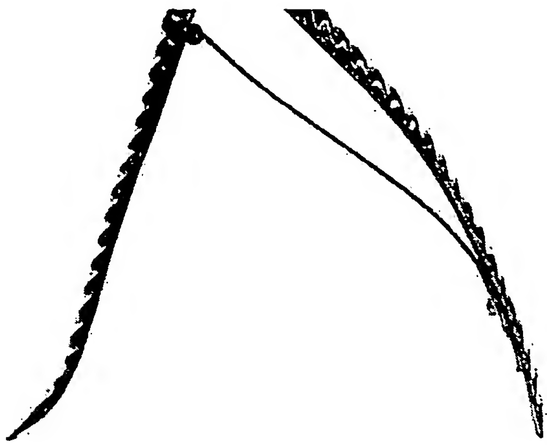

Fig. 11.4. Handle serrations, designed to injure surgeon's hand.

smooth handles, has handle knurling apparently specifically designed to cut or blister the surgeon's hand (Fig. 11.4).

Forceps

One of the most useful instruments in neurosurgery is the forceps. Coming in many styles, they are used for dissection, separation, picking up, holding, moving, coagulating, compressing, and even perforating structures. The jeweler's forceps is a time-worn instrument, supremely valuable in vascular microsurgery. As used by the watchmaker, its design is unchanged for more than a century. The neurosurgeon, working in the microscope field rather than 5 cm from his nose with the monocular jeweler's loupe, requires modification of the design. Lengthening the handle to provide support on the thenar web and improved balance is the most obvious modification. For surface work the jeweler's forceps, whether lengthened or not, is a good instrument. It should be available with several sizes of tips, from very fine to rather blunt. Its simplicity makes its smooth approximation good without all of the modifications required in the instrumentation for deep cavities, the long bayonet instruments.

The bayonet forceps must have tips 10 to 13 cm in length and must have proper stops so that the surgeon may squeeze as hard as he wishes without misalignment or crossing. Introduction of a single stop in a forceps usually makes it worse than if none were placed, since excess pressure past the stop produces separation of the tips. Accordingly, double stops are required, one proximal and one distal to the gripped area (Fig. 11.5). Suture pads were added to many tying forceps to permit accurate alignment and a nonslipping grip. Obviously, if the forceps is to hold the suture well, it must exert an even pressure from the tips backward for almost a centimeter. If the forceps blades are in apposition for several centimeters, the distribution of pressures will make the tip pressure too small. If the tips angle toward each other acutely, the suture may be behind the area of pressure altogether.

Tying pads were the obvious answer. They also permitted use of special materials such as carbide inserts, which were at times disappointing, since they tended to cut the suture. When the design of the forceps stops is sufficiently well executed, tying platforms may be dispensed with. A proper bayonet forceps, without pads, for example, should be able to hold 8–0 or 10–0 monofilament nylon at its tip with sufficient pressure to permit two such forceps to be used to tie a knot and pull it tightly and securely without slipping, over a full range of handle pressures. The generalizations discussed earlier regarding tip size, color and reflectivity, hardness and choice of metal are most important in these long, critically precise instruments. Titanium again is a great advance.

In any forceps the spring tension is critical, partly because a gentle predictable pressure is required for fine control. Perhaps as important is the use of the spring tension for separation of the tips to allow the use of the forceps as a dissector. Macrosurgical techniques often involved opening a scissors or hemostat to spread or separate tissues. The controlled opening of a pair of forceps tips in its own springiness is the microsurgical equivalent. Single-instrument dissection is rarely permissible, since it means pulling tissue away from delicate structures, with little control of the points of separation.

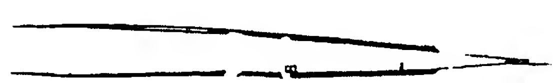

Fig. 11.5 Double stops and alignment guide in bayonet forceps.

Fig. 11.6. Gerald-style forceps fabricated as bipolar forceps.

Spreading of the forceps tips, or using two instruments simultaneously for dissection, controls the direction of applied force and so the line of separation. Since the forceps is held in one hand to accomplish this dissection, it frees the other hand for the use of another instrument, at times virtually providing a third hand. Spring tension of the forceps should be carefully graded in manufacture. It should be very light in the fine-tipped forceps, and progressively stronger with the heavier tips.

For a general-purpose forceps, and the most used bipolar coagulator forceps, a modification of the Gerald forceps is used. This design provides greater strength since it narrows only in the distal few centimeters. When made as an angled bayonet with proper stops, it becomes the best all-around dissecting forceps, in regular or bipolar configuration (Fig.11.6).

Scissors

Ring scissors are generally a poor choice for microsurgery; spring scissors provide an acceptable solution. Scissors for microsurgery, like the forceps, need be selected in two sizes: short and straight for surface work and long and bayoneted for deep cavities. The basic design has proved to be easily modified to provide a properly balanced small instrument or a long bayonet (Fig 11.7). In either form it is precise, highly maneuverable, and readily controlled. The angle of opening of the microscissor should be approximately 10 degrees. A greater angle overspreads the handle and reduces the delicacy or control. Several blade sizes are required, as are straight blades and blades curved both up and down relative to the bayonet.

Precision of size, of curvature, and of alignment of scissors tips has been a difficult problem for instrument manufacturers of macroinstruments and is even more so for manufacturers of microvascular instruments. In steel hardness of the edge material is reasonably easy to achieve, but corrosion resistance appears to vary inversely with the hardness and sharpness of the edge. The superior cutting edge of the newly purchased scissors may, after a few usages, push the tissue out of its grasp instead of dividing. Titanium is unsurpassed in its resistance to corrosion and sterilization damage, but more difficult to bring to a properly sharp edge. Although the titanium microscissors made by Codman are quite satisfactory, the fact that a finer edge can be produced and can be maintained has been demonstrated by the Greishaber Instrument Company. Known mainly for ocular instrumentation, they reprocessed several of my titanium instruments to a cutting quality I had not believed possible, though the cost was multiplied several times over.

The use of carbide or diamond inserts is often highly desirable for macroscissors because of

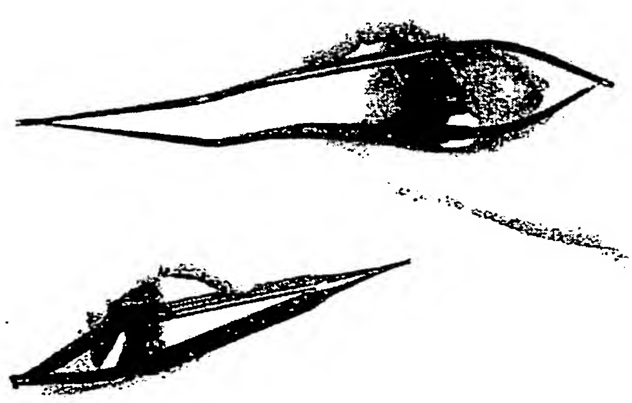

Fig. 11.7. Spring scissors in short straight and long bayonet models.

superior hardness and durability. In microvascular work these inserts do not have quite the smooth and effortless cutting feel that I prefer. Their intrinsic graininess, though minute, imports a sense of sawlike roughness that interferes with the desired delicacy when a vessel wall is to be prepared. Scissors with such inserts may do very well for exposure, dissection, and cutting of coagulated areas. It is relatively easy to visually check a scissors blade. If the open scissors is held cutting-edge up and rotated a few degrees under the microscope, there should be no reflection from the cutting edge. It should indeed appear to cut the light, leaving the edge black. Minute dulled spots or imperfections will shine brightly. A badly dulled blade will glow along the entire length of the supposed cutting edge.

Sharpening of scissors is a special skill that requires considerable practice. A proper hone, with fine diamond-coated surface, is required for carbide instruments. A carbide hone is used for rough cutting of steel or titanium, and final polishing is done with a ceramic hone. The secret of true scissor sharpening is in making each stroke of the hone as close to the same angle as possible. The correct angle for most scissors is about 5 degrees from square. It is proper to determine the angle of the original blade edge and then to approximately duplicate it as long as the edge is sharp. Hones should be lubricated always. Only a very badly damaged blade would need rough cutting to a degree that would permit a dry stone. The use of an electrically powered hone (RX Honing Machine Corporation) makes the process faster and easier, and the skill required is less. I have gotten into the habit of regularly resharpening my own tools to avoid the long delays in sending the instruments out and the questionable quality control visible on their return. It takes very few minutes each week to assure first-class cutting edges. I use the electrical reciprocating hone routinely.

On macroscissors, the regular ring-type, the precision of the joint bearing is critical. Smooth, effortless movement must be coupled with virtual absence of play, lest the scissors blades separate and pinch the tissue instead of cutting. The difficulty is compounded in the ring scissors by the stress that may be applied to the rings to lever the blades apart rather than together as well as by the rapid wear either direction of stress produces. In the spring microscissor, stress on the joint is minimized by the absence of lateral leverage from the handle. However, the lightness and fineness of the joint make it vulnerable to the stresses applied by the blades, and the thin fine blades may themselves be bent out of alignment. This dictates compromises. Thicker joints with larger screws and thicker blades cut much better, but are heavier and more awkward to use. The lightest most delicate instrument that will hold alignment becomes a triumph of the instrument maker's skill.

In microsurgery, ring scissors long enough to work in a deep field can have advantages in ease of control because of its secure support in the hand as compared with the fingertips holding the spring scissors. Such ring scissors, because of its delicacy, would quickly have its joint bearing damaged by the lateral stress on the rings. Accordingly, a guide was incorporated which maintains the alignment of the handles, and so of the blades, and protects the joints (Fig. 11.8). It has worked out well in practice.

Spring tension should be adjustable without damage to any spring instrument whether scissors or needle holders. The directions for this adjustment unfortunately rarely reach the surgeon, as the new instruments are unpacked by the operating room staff, and the instructions and boxes discarded. Actually the tension adjustment is quite easy. To increase the tension, the spring is gently rolled outward between the thumb and forefingers so that the spring takes on a sharper curve (Fig. 11.9). To decrease the tension, the arms are squeezed together so that they take on a flatter, more gentle curve.

I have not found the so-called pencil-style scissors helpful. Its design seems to provide lit-

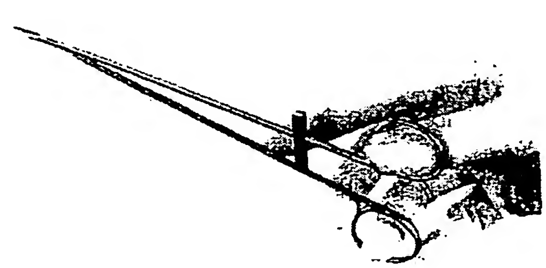

Fig. 11.8. Ring-type microscissors with lateral alignment guide.

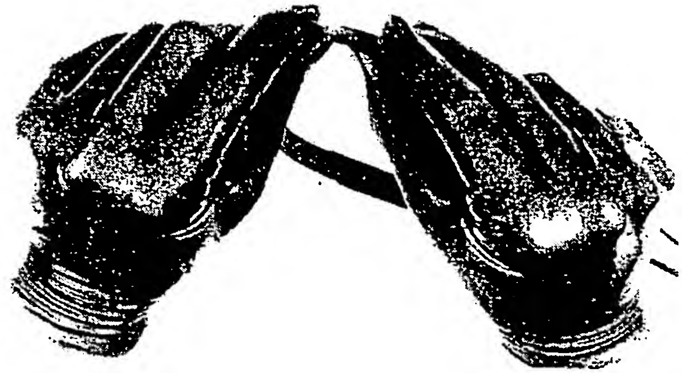

Fig. 11.9. Adjusting tension on spring instrument.

tle guidance or support for the tip, since both levers must be squeezed to cut. A better design would have one fixed blade and a single lever to move the other blade.

Needle Holders

The same basic spring design is used for needle holders, so important in microvascular techniques. Again the handle length has been increased to allow it to rest on the thenar web, so that the small straight-handled instruments have good balance. The traditional locks have been altered so that they may be used to fix the needle in the holder to bring it to the field. Squeezing a bit further releases the lock, and then the needle holder may be gently used, holding the needle only by the surgeon's finger tension while the needle is passed. When pressure is released, there is no lock to hold or jar the needle. Although less frequently used than the surface instruments, long bayonet needle holders of the same design work very well in deep operative exposures. The same considerations regarding the locks apply.

The tips of needle holders must also be a compromise. The requirement is secure, nondestructive holding of a microneedle, with the lightest, most delicate tip possible. With currently used 4-mm chord length needles, and with the 2-mm chord length needles used for special applications, a 1-mm wide needle holder tip will both deform and obscure the needle. A smooth tip will allow the needle to slide and twist unless it is excessively wide. A grooved or serrated surface fine enough to hold a needle cannot be adequately cleaned even with ultrasonic cleaning devices. Although titanium needle holders appear superior to stainless steel, carbide or diamond inserts are somewhat better in prolonged use and will more securely hold a round-bodied needle. These inserts prevent magnetic sticking, which may occur as a steel needle holder becomes magnetized. Titanium instruments cannot be magnetized, of course. Most needles in the microvascular sizes are now oval or flat-bodied, making them almost unrotatable and harder to turn from the desired angle. Cup-shaped needle-holder tips, if used only with the one needle size and curve for which they were specifically designed, securely hold a needle, but again, only in the one position for which they are shaped.

For needles from 70 to 130 μ in diameter, I prefer a general-purpose flat-surfaced tip with carbide or diamond insert, about 0.5 mm in width, and a separate ultra-fine holder of titanium, more delicate throughout, without inserts, with a 0.3-mm tip width for the 30- to 50-μ needles. These needle holders can readily be damaged if too large a needle is used. A separate larger holder with a tip almost 1 mm in width and carbide or diamond inserts is used for the heavier needles that may carry 6-0 suture material.

Needles and suture material will be only very briefly noted here, since their use will be covered in other chapters. The *United States Pharmacopeia* has published a suture classification

for nonabsorbable microsutures with labeling uniform as of July 1980, as follows:

USP Size	Microns
12–0	1–9
11–0	10–19
10–0	20–29
9–0	30–39
8–0	40–49
7–0	50–69

This grading classification does have quite a range in the smaller sizes; for example, the 14-μm and 18-μm sutures are both available—the 14-μm sutures on the 30-μm needle and the 18-μm suture on the 50-μm needle—but both are listed as 11-0 suture. Needles have not yet been standardized, but Ethicon, for example, in concert with many neurosurgeons on their advisory panels, has now set up a needle nomenclature that permits recognition. The variables to be covered in microvascular needles are straight or fraction of circle, chord length, and wire diameter. "BV" has been the Ethicon designation for a ⅜ circle needle, BVH for a ½ circle needle, and ST for a straight needle. This is now followed by the wire diameter in microns and the chord length in millimeters. The most commonly used needle in the old arbitrary numbering was the BV-6. This needle is a ⅜ circle, 75 μm in diameter with a chord length of 4 mm. It is now called a BV 75-4. The smallest diameter needle now available is 30 μm. It is made only in a 2-mm length (which is also the shortest needle now made) with a 11-0 suture that is 14 μm in diameter. It is not commercially feasible to fit a suture material into a needle less than double the diameter of the suture. Within this constraint almost any reasonable combination is available.

Knives

Knife blades for work under the microscope present a special problem. The best scalpel blades available in their presterilized packages are simply not sharp enough and will not smoothly separate arachnoid from a vessel. The old-fashioned carbon steel razor blades, gas autoclaved (steam autoclaving will destroy the edge quite effectively) when broken with a blade breaker and held in a suitable holder, were usually sharp enough to do the job well. The razor blade manufacturers changed to the production of flexible platinum stainless steels, which break very poorly and tend to curl up. It became exceedingly difficult to obtain the older type of brittle blades that we had been using.

Very fine knives such as cataract knives and trigeminal hook knives modified for microneurosurgery have been unsatisfactory in our hands because of the inability to keep them suitably sharp. I have spent hours honing them under the microscope until they were just exactly right only to have them handed to me the next day with the edge ruined because of having bumped just one other instrument. In addition, the edge one achieves is never really as good as that of a commercial razor blade.

None of the diamond dust or carbide materials has been suitable for manufacture into a proper blade. A virtually perfect knife blade in terms of sharpness can be made by polishing a gem-quality diamond to a suitable cutting edge and cementing it into a properly oriented surgical handle. Such a blade is sharper than a razor blade and virtually parts tissue on contact. It has, unfortunately, no flexibility. It has not yet been possible to make it with a curved edge. Thus, its cutting will be done with the point rather than with a proper curved belly. Furthermore, the tip is brittle and will not survive a fall or blow from another instrument. Considering the cost, the fragility is too great to permit it to be recommended at this time.

The platinum stainless razor blade turned out to be a serendipitous solution. Cutting the blade segments with a special shear solved the problem of our inability to break them, and their flexibility turned out to be a superb advantage. Anyone who has learned to fillet a fish knows that the filleting knife must be thin and very flexible. If a stiff blade is used, either the fish bones are cut, or the meat is left attached and wasted. A flexible blade guides itself along the fish's bony skeleton, neatly separating the fillet. Quite the same thing happens with the platinum stainless blade. Its flexibility guides it along minor differences in density, filleting arachnoid off vessels and separating vascular and neural structures.

The segments of platinum stainless double-edged razor blades are cut, dozens at a session, using the special shear (Fig. 11.10). The seg-

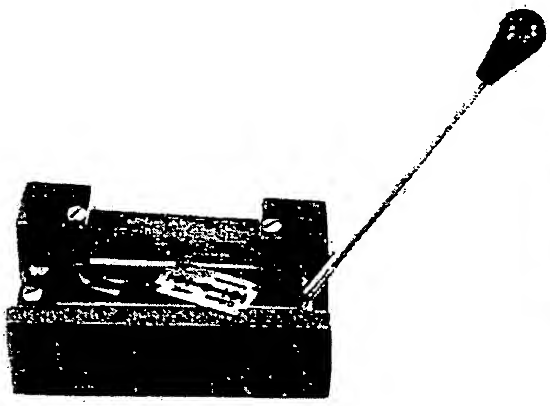

Fig. 11.10. Shear for precise cutting of platinum stainless razor blades.

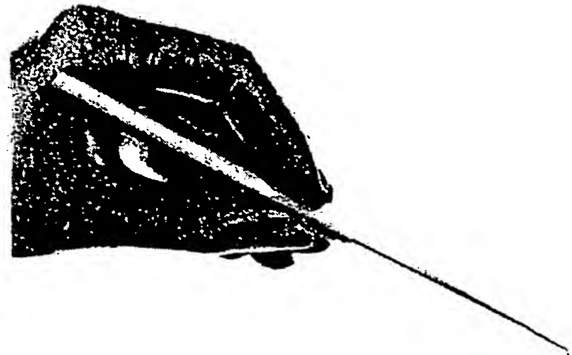

Fig. 11.11. Nerve with flat surface ground into handle to indicate direction of hook.

ments are generally 1 cm in length and 3 mm in width at the base and, of course, come to a point at the other end. Five or six such segments are packed together and gas-autoclaved for stock, to be added to the set as needed. Depending on the delicacy of the procedure and the need to avoid pressure or tension during the sharp dissection, blades may have to be replaced every few strokes. A second blade holder is therefore prepared while the first one is in use.

Nerve Hooks and Dissectors

Several sizes of nerve hooks are needed, particularly to gently lift and move structures already dissected. I believe that dissecting with a nerve hook or almost any single dissector is seldom good practice, since it involves traction on the attached structures. Such dissection should generally be sharp with razor blade or scissors or carried out with two separating points, as achieved when a forceps is allowed to spread with its own spring tension. Of course, hooks or dissectors may be used in pairs, one in each hand, so that the direction of tension and separation may be controlled. At times one dissector may be used, with the suction or with the forceps held in the other hand to provide the counterforce. Nerve hooks and other dissectors with angled ends should have some indication at the handle end to show the direction of the working tip. If a hook has been rotated between structures, the tip may be concealed and becomes most hazardous to manipulate without external guidance. Accordingly, I have always ground a flat surface on the handle to indicate the direction of the hook (Fig. 11.11).

Single and double forks with fine-wire tips with ball ends can be useful in anastomosis. The single ball may be used to remove a bit of intraluminal clot without endothelial injury. The end of a plastic stent or a T tube can be more easily passed into a small lumen between the tines of the double fork. It may also be used as an atraumatic counter pressor, though it requires changing instruments. Avoiding this extra step usually means using the more dangerous angular tips of the microforceps as a fork.

Alligator Configuration

An entire group of instruments, designed with what has been called the alligator shape, comprises such standard items in the neurosurgical armamentarium as a pituitary cup forceps or a bone punch. Microsurgical instruments with the same shape also have a wide field of usefulness. Direct derivatives of the pituitary forceps with various small cup sizes down to 1 mm have been made available. A 2 × 4-mm cup in a lightweight instrument with relatively long blades is useful, but an entire lineup of multiple cup sizes scarcely appears necessary. Punches have also been thinned down to levels too flimsy to use, with various intermediate compromises resembling the otolaryngologist's sphenoid punch. I have a personal prejudice against multipurpose

tools that have to be rotated and set for each new use. It appears to me a reasonable indulgence to purchase four individual punches that cut up, down, right, and left, rather than one instrument that rotates and that one must wait for between bites. In addition, the rotating instrument always takes up more room than the single-purpose punch. Although they reduce the number of instruments in the set, I can think of no other advantage for the multiposition punches that would offset their inadequate human engineering.

Fine forceps have been made with the alligator design and can be most useful for grasping a structure through a small opening. Using such forceps for dissecting is another matter, however. The amount of leverage afforded by this design as the points are separated destroys the ability to feel the structure being separated. At the same time, an excessive amount of force can be applied with minimum effort. In addition, the position of the joint and fixed section often obscures the view between the tips unless the angle is just right. The arc through which the forceps tip opens is so short that the pressure tends to be produced right at the point. This is in contrast to the dissection with the long bayonet, where the separation tends to be almost parallel, the operator looks down between the blades as they separate, and the amount of pressure to be applied cannot be higher than that of the spring tension of the forceps and is readily controlled by the tactile sense in the surgeon's hand. It is generally better, therefore, to use the alligator forceps as a grasping instrument rather than as a dissecting instrument. Alligator scissors are required for such procedures as transphenoidal hypophysectomy and are also highly useful for many other applications where the entering space is too narrow for the spring design. Nevertheless, I find their balance and control less satisfying than that afforded by the spring design. I find that I never use the alligator scissors anywhere that a spring type will fit.

Fine, long alligator forceps and scissors are available with a tubular design. The outer cylinder tubing is fixed, with a moving actuator inside the tubing. These instruments take little room in the operative field and can work through a small opening. As a matter of personal prejudice, I have excluded them from my armamentarium because I believe them to be impossible to clean adequately, particularly if blood gets into the tubing.

Suction

Suction devices are particularly important. An absolute essential is a regulated suction pressure, and one must have a suction unit that is predictable within the soft ranges of 40, 60, 80, or 100 mm Hg. Such suction regulators have a preset pressure gauge that is adjusted to the maximum negative pressure desired. If set, for example, to 80 mm, this device will hold at 80 mm when completely occluded, and when opened, it will still provide an effective 80 mm through a large-gauge suction tube. We have been using the Suction ReguGage by Chemtron for many years. The full vacuum of 300 mm commonly used and available in operating wall suction systems is much too hazardous for the microneurosurgeon. Even relatively large-caliber suction devices can be most effective in keeping the field clear in case of catastrophic bleeding without the danger of sucking in vital structures if they are set at a suitable low pressure. We customarily set up two suction systems, one of which is connected to the full vacuum line and used only outside of the dura. The other is the soft suction connected through a reduction regulator and used for most procedures intradurally. In addition to the standard 7 Fr suctions, we also use fine-diameter suction tips. These are made up by using an ordinary suction that has been cut off just at the curve and a Luer lock connector tip attached at that point. Long spinal needles with their beveled points cut off and the ends suitably rounded are kept in pairs with stylets for attachment to the Luer lock (Fig. 11.12). If one needle clogs it is simply interchanged by the nurse for the other one of the same size while the first one is cleared and made ready again.

For working in the subarachnoid space, as in separating the arachnoid from vessels along the Sylvian fissure or along the optic chiasm, the controlled soft suction with a size 7 Fr suction tip will provide rapid clearing of fluid and permit a clear field without damaging the adjacent structures. In case of major bleeding as from a ruptured aneurysm, a larger diameter suction tip can be put on the soft suction and will permit

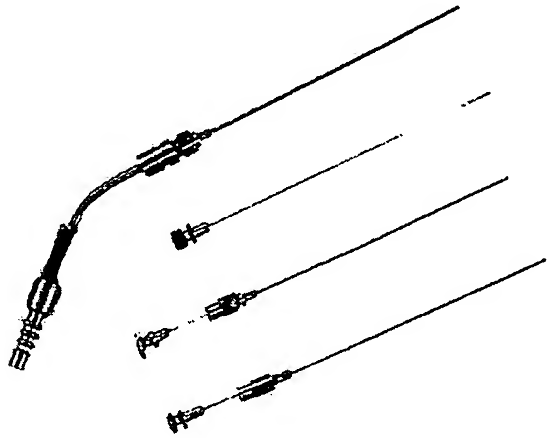

Fig. 11.12. Microsuction with replaceable blunt spinal needles for tips.

the clearing of a great deal of blood without tearing or sucking in vital arterial branches. Here the temptation to use the high vacuum should be resisted if possible. The soft suction is regularly used directly on tissue, without an intervening cottonoid. It becomes one side of the dissecting pair when a nerve hook or other microdissector is used in the other hand. With the bipolar forceps in the right hand, the soft suction is used in the left hand to provide retraction, counter pressure, dissection, and suction simultaneously. To increase the delicacy of the suction tip used this way, a 1-mm side hole may be drilled through the #7 suction 1-mm from its tip. This prevents occluding the suction when the tip contacts a neural or vascular structure and permits the suction to continue aspirating fluid. This is now the standard for most of our suction tip usage.

Bipolar Coagulator

Bipolar coagulation has been part of microneurosurgical technique from the very beginning. The old standard unipolar machines worked from a single active electrode to a return plate through a large ground plate or dispersive electrode. A rather large current, distributed roughly in a geometric cone from the active electrode to the ground plate, had its highest power per tissue volume at the active electrode, but a fairly large amount of current was distributed in adjacent tissues. The most conductive path to ground had the highest current density. This could be through the blood in a small vessel being coagulated, thereby coagulating the parent vessel inadvertently. Use of the unipolar coagulator under saline irrigation was not feasible, as the saline was the conductive path to ground rather than the desired tissue.

In bipolar coagulation the electrical difference is only in the isolated output and in the lower power requirements. The output of the bipolar generator should be as completely isolated from ground as possible, so that all current flow takes place between the two tips of the separated forceps. There should be no significant current flow from either side of the forceps to ground. The current geometry will now be dependent on the tip size and the angle at which the tips meet as well as the medium in which they are immersed. If the forceps blades are almost parallel, and the forceps are deep in saline, there will be major shunting in the saline (Fig. 11.13A). If the forceps are bowed or angled so that the tips almost meet while the blades are still well separated, the current flow will be mainly between the tips, with less shunting (Fig. 11.13B).

Electrically, the waveform and current characteristics required are like those for unipolar coagulation. Repetitive bursts of electrical spike discharges at changing intervals, with each spike varying about a microsecond in duration, a randomly varying interspike interval within the burst, and a decreasing amplitude within each burst give the best coagulation with the least cutting or perforation and the least muscle stimulation. The lowest output impedance, providing a stiffly regulated constant voltage output, permits the unit to work well under saline irrigation.

Fig. 11.13A. Incorrect bipolar tip configuration.

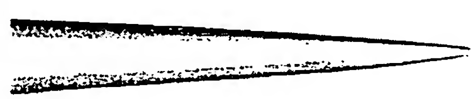

Fig. 11.13B. Correct bipolar tip configuration.

This waveform only had been possible with spark generators until very recently. Microprocessor control and newly developed output transistors have now permitted the design of a solid state bipolar coagulator combining the proper asynchronous waveform with very low output impedance. The spark generator had produced a higher voltage spike at the beginning of each burst, inherent in spark gap technology. This high first spike was able to be eliminated in the new solid state generator resulting in much smoother, gentler coagulation with much less tendency to char, stick, or perforate.

The forceps tip size is critical, since current density determines results. Although cutting occurs most easily with a smooth, continuous sinusoidal wave form, the best coagulating waveform will cut if the current density is high enough, and a cutting waveform will heat and even cook if the current density is low. This difference is often the result of the electrode or forceps tip size. At the same power settings, a very fine forceps will perforate an arteriovenous malformation whereas a larger forceps can simply permit stroking, shrinking, and progressive coagulation. At lower power settings the very fine forceps tip permits precise coagulation of small vessels on the brainstem or cord. Under saline irrigation there will be no measurable heating of adjacent tissue. If a small vessel branch has been avulsed from a larger trunk, a blunt bipolar tip, slightly larger than the opening, can be used to seal the perforation without further damage to the involved vessel.

Of course, if the bipolar tips contact each other, the current is short-circuited and no coagulation takes place. If a coagulum of blood is baked on the tip surface, it is an effective insulator. Little current flows and little coagulation occurs. It is essential that the forceps tip be kept clean, shiny, and unpitted. A pitted forceps cannot be kept clean and will stick to tissue. Pitting is avoided by not sparking the forceps and by constant saline irrigation as well as by low-power settings. It is corrected by honing the tip surfaces smooth. The scrub nurse keeps the tips clean during the operation using a small, gently abrasive, sterile disposable pad.

The settings that I use most often on my own coagulator are never over 60. Fifty and 60 are used only outside the skull or spinal canal, for muscle or superficial vessels. Most intracranial and intraspinal tumor work is done at 35 or 40. Vascular lesions are usually handled at 30. Vessel perforations are sealed at 25, and aneurysm necks shrunken at 20 or 25. For secure arterial coagulation, a length of the vessel at least several times the diameter should be occluded. If possible, a branch should be sealed right against the parent trunk. In arteriovenous malformations, because of the high postoperative pressure gradient, clips are suggested for vessels more than 0.5 mm in diameter, whereas normal or tumor vessels several times that size may be safely coagulated without clips. I always use the bipolar under irrigation.

Suction irrigators, although convenient, relieve the assistant of the need to follow the surgery and may interfere with a teaching program, since the degree of involvement can be so little. Suction bipolar forceps have been either too heavy for my taste or if made finer, clog constantly. Many years ago, when working alone at the operative table in the electrophysiology laboratory, I used a fine irrigating needle attached to the blade of my bipolar forceps, ending about 5 mm from the tip. The fluid was supplied by a standard IV saline drip connection. Although this was very useful in the total absence of any assistant or nurse, I happily discarded it when I moved into the operating room.

I believe the use of automatic irrigators controlled by the bipolar coagulation pedal to be most hazardous. If for any reason, the forceps are angled upward, as they may be with the patient in the sitting position, no fluid will run up the forceps tip from the irrigating tube and there may be no irrigation at a particularly critical point in the procedure. When working downward in a deep crevice where the subarachnoid fluid may already be providing more than enough irrigation, additional irrigating solution can obscure the field, again, at a critical moment. I believe that for the operating room, the control of irrigation requires direct decision making by a qualified assistant.

The irrigating syringe we now use is the Davol bulb syringe to which is attached a White chip syringe metal tip (Fig. 11.14). The assistant sees to it that the field is moistened each time that he is to step on the bipolar pedal, and so remains part of the operative team. Bulb syringes used for irrigation should never be cleaned with detergents. Their inner surface

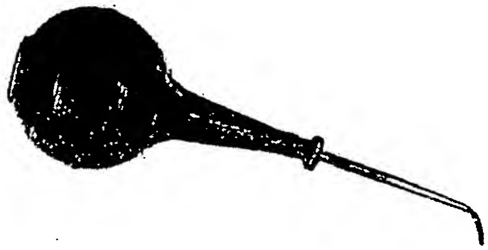

Fig. 11.14. Irrigating syringe.

cannot be adequately freed of the detergents, some of which are neurotoxic despite great dilution.

Finally, we use saline irrigation rather than any more complex solution, and I use it at room temperature, rather than attempting to keep the irrigation at a more physiologic temperature. This choice was based on years of animal-evoked potential work, where we eventually found this simple technique caused the least problems. It has been the standard in our hospital for more than 20 years and has been completely satisfactory.

Hemostatic Clips

The original Cushing silver clips closed as a "V," sometimes pushing the structure being clipped out of the clip as the clip was being closed. The Weck Company's "Hemoclip" and Ethicon's "Ligaclip" are "U" shaped as loaded and close first at the tips, then flatten out to occlude the clipped structure. Both Hemoclips and Ligaclips are supplied with the tantalum clips preloaded in plastic racks in small, medium, and large sizes. The clip appliers for the Ligaclips and Hemoclips are not interchangeable, and neither can interchange with the older Cushing clip forceps.

All clips and appliers require a great deal more precision than is readily apparent. The tip grooves of the applier particularly must hold the clip when open, but not be tight enough to prevent the release of the closed clip and not be easily filled with clot or debris, which can make the clip stick in the applier. This can create one of the most dangerous and difficult moments in surgery. A branch of an important vessel has been clipped deep in the wound, and the clip remains firmly stuck in the groove in one side of the clip forceps. If one has been fortunate enough not to tear the vessel before realizing the situation, one may manage to pry the clip out of the groove with another instrument. Pretesting and rejection of the mismatches should preclude this situation, but we need instrumentation that would eliminate all such possibilities. The end groove in the clip forceps should always be minutely wider at its open edge than at the depth of the groove. Whatever clip forceps is used, the temptation to overclose the applier must be avoided, for it can cause crushing or cutting of the vessel or force scissoring of the clip. On the other hand, rigid quality control by the manufacturer is required to see that the clip racks are uniform, that the clips have both legs of equal length, and that their clip forceps are exactly sized. For microneurosurgery, an alligator applier is essential in deep, narrow openings. The Weck alligator applier seems to me far too heavy in the handle tubing and its spring return so overloaded that all gentleness and delicacy is lost. At present I use a Ligaclip alligator applier, which has been very satisfactory, but it is a prototype instrument, not yet available for purchase.

Clips

Temporary clips are an obvious necessity for vascular reconstruction. The foremost requirement, secure occlusion with minimal vessel trauma, is a difficult achievement. The stress on a vessel will clearly be greatest near the clip fulcrum. A short clip may hold with little pressure, but the pressure gradient from proximal to distal may be great. A long clip, placed so the vessel is only at the distal end of the blade, has the least gradient. Bending the blades inward so that they meet at the tip while still a few hundred microns open more proximally, provided security with the least gradient.

Mayfield clips lose their strength if squeezed firmly once or twice before applying. They can only be used for permanent clips if care is taken to prevent their prior use or misuse. I take advantage of this quality to use Mayfield clips as my temporary clips. I squeeze them by hand first and then bend the long blades slightly inward. Determining the least occlusive pressure takes very little practice, and the pressure can

readily be altered for different vessels. William's temporary clip may well be the least traumatic device, but only prototypes have so far been available. The clip occludes the vessel by using a fine rod to flex the vessel between two separated fine rods on the other side, giving no actual compressive force on the vessel wall.

The special topic of aneurysm clips and their appliers will be covered in Chapter 17 of Volume III and will not be discussed here.

Retractors

Microsurgery with hand retraction seems almost unthinkable for me. Although actual retraction in the sense of pulling on structures is not done, areas must be elevated, supported, and moved into their required position and maintained there with appropriate control of pressure. Self-retaining brain retractors, of which many types have been available for years prior to the introduction of the microscope, have been adapted and new retractors developed. A proper self-retaining retractor must fulfill a number of requirements. It must be able to curve along whatever surface or plane is desired, be variable in width and length, and enter from any direction. It must be uncomplicated, easily and rapidly placed, and readily shifted as needed when the procedure progresses. It must not move when pressure is made upon the head. It should provide sufficient ridigity to prevent the catastrophic trauma that might occur if an inadequately fixed blade were inadvertently bumped and so displaced. Finally, the apparatus must not get in the way of the operator or assistant, or produce artificial depth in the wound. Multiple cross bars and stepwise systems are, to me, an effective barricade, interfering with adequate exposure and operative technique.

Although the use of the pinned headrest has become a universal requirement, several millimeters of movement is still possible between the operative site and the clamp, and almost a centimeter of movement between the operative area and the operating table, if pressure is made upon the head. Accordingly, I do not use any retractor attachment to the table or the head clamps. All retractors are secured only to the head.

Most flexbar-type retractors require table mounting, or at least head-clamp mounting, but a few lighter weight flexbar modifications can be attached to the skull. They provide fast and easy placement as well as ability to follow the dissection without waste of time or motions. They can be placed so that they enter from any direction and do not obstruct the field. Nevertheless, I personally find them unsatisfactory because I am unable to fix the flexbar rigidly enough to prevent accidents. Particularly in the passage of an instrument into the field, the central wire in the flexbar cannot be forced tight enough to prevent this movement in any size of flexbar reasonable enough for our use.

I use an offset skull fixation retractor clamp, the offset keeping the apparatus away from the wound, avoiding obstruction of the field. It is generally placed so that its foot is subdural, clamping the dura to the calvarium. The more customary epidural placement carries a risk of epidural bleeding that need not be accepted. All of the bars, that on the skull fixation clamp, the intermediate bar, and the retractor bar itself, are the same diameter, permitting complete interchangeability. They are ¼ inch in diameter instead of the ⅛ inch of some of the older retractors, which doubles the clamped surface, increasing grip and decreasing tendency to slip.

The intermediate clamps are designed to grip or release only one bar with each knob. Extension bars permit entrance of the retractor from any direction or position, regardless of placement of the skull fixation clamp. The extension bars and clamps are placed flat against the surrounding draped area, not obstructing the field or deepening it (Fig. 11.15). Bars of the same diameter have been added to the straight Weitlaner retractors or the modified curved Adson cerebellar retractors, which we normally use for either extracranial posterior fossa or laminectomy muscle retractors, and the self-retaining brain retractor set may be mounted to these bars instead of using skeletal fixation (Fig. 11.16).

As stated, retractors are really used for support and positioning of structures rather than actual retraction. Retractor pressures over 10 torr in the hypotensive patient and 20 torr in the normotensive patient are likely to produce subcortical necrosis. Training in the estimation of retractor pressures is carried out in the labora-

Fig. 11.15. Self-retaining retractor with skull fixation.

tory with a water manometer to which is attached a water-filled finger cot. The pressure of the retractor blade required to lift the water 13 cm (10 torr) or 26 cm (20 torr) is readily learned. Albin's monitoring retractor, with a continous digital readout of retractor pressure, works quite well. Using it in my operating room, I was able to confirm my impression that my retractor presssure rarely reached 5 or 6 torr.

I use the widest retractor blade that will fit the exposure, to minimize distortion of the brain, and curve the blades to allow the handle bars to lie flat against the surround. The wide blade also provides protection for the brain against an instrument being awkwardly introduced into the field. The stainless retractor blades are permanently sealed within a Teflon coating, so that they require no cottonoid or collagen layer beneath them, allowing easier placement and replacement. The same retractor blades may carry embedded evoked potential electrodes or an Albin pressure sensor, as desired.

Arm Rest

An arm rest or support is a virtual necessity for steadiness, particularly in long operations. I have used a simple modification of a Mayo stand for all microsurgical procedures for the past 12 years. The Mayo stand is cut apart, narrowed to a 5-inch width, and either bolted or welded back together (Fig. 11.17). It is covered

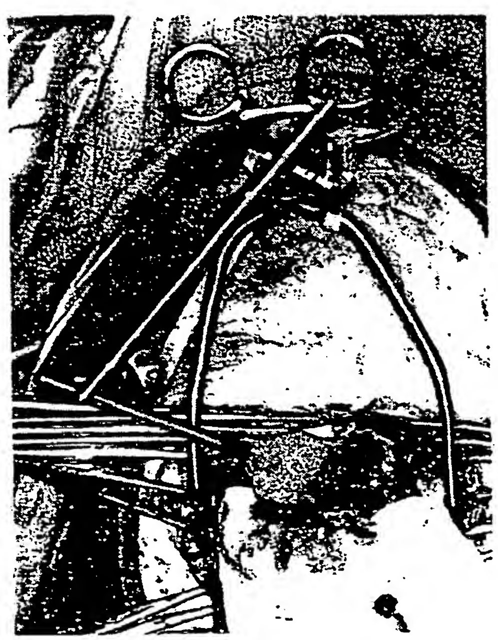

Fig. 11.16. Self-retaining retractor with muscle fixation.

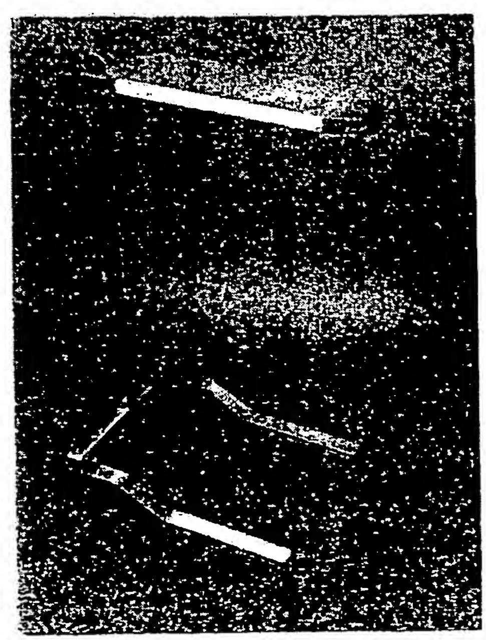

Fig. 11.17. Mayo stand cut and rejoined to make a narrow arm rest.

with a stainless metal plate and then permanently padded with an inch or so of foam rubber and a plastic cover. In use, the sterile drape sheet includes a sterile waterproof plastic layer. The stand can be moved to position in any procedure, whether laminectomy or craniotomy, and its height changed at will. It gives support either to the elbows or forearms, as preferred. An instrument can be placed on it temporarily, if the scrub nurse will permit. Without obstructing the field, the movability, the broad area, and the padding provide the comfortable support needed when working many hours.

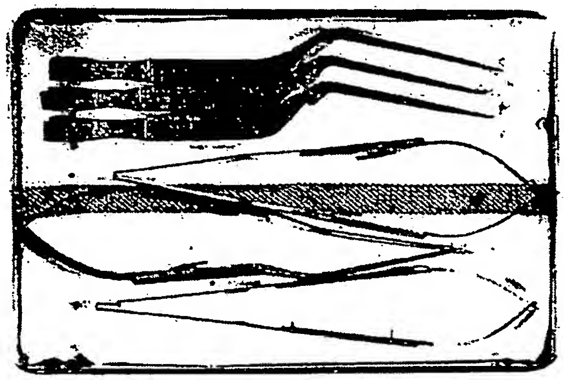

Fig. 11.18. Microinstruments in sterilization and storage tray.

Care of Microinstruments

Microinstruments cannot be piled in a tray and put through routine cleaning and sterilization with ordinary instruments, unless one would like to consider these precise, delicate, and extremely expensive tools as essentially disposable. The alignment of forceps can be destroyed by piling heavy objects on them, and fine tips are too readily ruined even with careful handling. The major essential is a dedicated individual, a microneurosurgically trained operating room person who knows the use and appreciates the delicacy of the instruments and has seen them under the microscope. The care problem cannot be solved by providing special cases or holders, since, if the proper personal care is not available, these trays or cases become just another thing on which to break an instrument. The available instrument racks have been constructed in such a manner that it is too difficult to get instruments in and out. If they are made, instead, so that access is easy, the instruments are likely to be damaged during cleaning or sterilization, as they are not secured firmly enough.

We have given up the special racks and now place our instruments on layers of towels in flat pans. The fine tips of each instrument are covered with small segments of latex tubing (Fig. 11.18). Instruments are individually cleaned and cared for, including lubrication, before placement in the trays. Ultrasonic cleaning of regular surgical instruments has become routine in many operating areas. If microsurgical instruments need ultrasonic cleaning, they must be placed individually, and for stainless tips, the tip should be held out of the cleaner. No fine edge, from diamond down, will withstand contact with any object or other instrument when in the ultrasonic field.

The new titanium instruments will permit steam autoclaving. However, if older sharp instruments of stainless steel are included in the set, these should not be steam autoclaved if their edges are to be preserved. Either the set may be divided, or the entire instrument pack may be gas autoclaved with ethylene oxide. In setting up for an operation, the instrument trays are placed on the instrument table, and those instruments that are expected to be used are laid out separately on a towel, while the others are left in the trays. After an instrument is used, it is placed in another towel. This permits selection of only those instruments that have been actually used and so require cleaning. The unused instruments can then be part of the pack for resterilization with minimum handling. Additionally, the availability of the instruments as placed in a row on a towel permits rapid scrub nurse service as compared with the longer delays when special racks are used. The major key to instrument care is still the microneurosurgical operating room nurse. Allowing a central sterile supply department to take over this responsibility is, to me, an unacceptable notion. The fact that microsurgical instrumentation has been able to reach its present standard is a mark of the special skills and knowledge applied by our specialized nursing teams.